Prognostic scoring in ruptured abdominal aortic aneurysm: A prospective evaluation

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Background: **Prospective validation of prognostic scoring systems for ruptured abdominal aortic aneurysm (AAA) is lacking. This study assesses the validity of three established risk scores and a new prognostic index.**

Method: **Patients admitted with ruptured AAA during a 26-month period (August 2002-December 2004) were recruited prospectively. The Glasgow Aneurysm Score (GAS), Hardman Index, Physiological and Operative Severity Score for enUmeration of Mortality and Morbidity (POSSUM) scores, and the Edinburgh Ruptured Aneurysm Score (ERAS) were recorded and related to outcome.**

Results: **During the study period, 111 patients were admitted with ruptured AAA. Of these, 84 (76%) underwent attempted operative repair and were included in the study; 37 (44%) died after operation. The GAS, Hardman Index, and the ERAS were statistically related to mortality. However, analysis by receiver-operator characteristic curve revealed the ERAS to have an area under the curve (AUC) of 0.72 (95% confidence interval [CI], 0.61-0.83). The vascular (V)-POSSUM and ruptured AAA (RAAA)-POSSUM models had an AUC of 0.70 (95% CI, 0.59-0.82). The Hardman Index and GAS had an AUC of 0.69 (95% CI, 0.57-0.80) and 0.64 (95% CI, 0.52-0.76), respectively. Although the V-POSSUM equation predicted mortality effectively ($P = .086$), the RAAA-POSSUM derivative demonstrated a significant lack of fit ($P = .009$).**

Conclusion: **Prospective validation shows that the Hardman Index, GAS, and V-POSSUM and RAAA-POSSUM scores do not perform well as predictors for death after ruptured AAA. The ERAS accurately stratifies perioperative risk but requires further validation. (J Vasc Surg 2008;47:282-6.)**

The incidence of patients presenting with ruptured abdominal aortic aneurysm (AAA) is increasing.[1,2] To ensure appropriate use of health care resources and avoid futile attempts at intervention in patients with prohibitive risk, judicious patient selection is essential. Upon presentation, the patient's clinical condition must be rapidly assessed to determine if attempted operation is appropriate and associated with a reasonable chance of survival. For the most part, this is largely a subjective decision; however, a scoring system that could accurately predict outcome in patients before operation would allow selection to be objective and more easily justified. Appropriate risk stratification of patients would also support comparative audit within and between institutions.

The Glasgow Aneurysm Score (GAS), Hardman Index, and Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM) risk equations are predictive scoring systems recommended for use in patients with ruptured AAA.[3-5] Recently, our center has developed the Edinburgh Ruptured Aneurysm Score (ERAS), a further novel prognostic index that, in contrast to other scores, was derived from a contemporary data set.[6] However, none of these scoring systems have been adequately validated to be of use in dictating therapy or justifying clinical decision making. This prospective study examined preoperative variables predictive of death after AAA rupture and assessed the validity of existing scoring systems.

METHOD

Local Research Ethics Committee approval was obtained for this prospective study. All patients admitted to the Edinburgh Vascular Surgical Service for repair of a ruptured AAA during a 2-year period (August 2002-December 2004) were included in this prospective study. Operation was defined as the delivery of an anesthetic with the intention of performing AAA repair. Ruptured AAA was defined as the presence of retroperitoneal or intraperitoneal blood, or both, in the absence of any other identifiable cause for hematoma other than an aneurysm.[7]

All patients were operated on by one of five consultant vascular surgeons. For each patient, 53 preoperative variables, identified in other studies or suspected on clinical grounds to be associated with mortality, the GAS, Hardman Index, V-POSSUM and ruptured AAA (RAAA)-POSSUM (physiology only) scores, and ERAS were recorded at the point of admission, before operation, and related to 30-day or in-hospital mortality. The protocols observed within our unit did not advocate the use of endovascular aortic repair for emergency AAA repair during the study period. Surgical intervention was generally not undertaken if the patient declined operation, had a known serious comorbidity such as advanced malignancy, or was

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Table I. POSSUM physiologic and operative variables

Physiologic	*Operative*
Age (years)	Operation category (minor, intermediate, major, major+)
Cardiac signs	Number of procedures
Respiratory signs	Total blood loss (mL)
Systolic blood pressure, mm Hg	Peritoneal soiling
Pulse rate/min	Malignancy
Glasgow Coma Score	Timing of operation
Serum urea, mmol/L	
Serum sodium, mmol/L	
Serum potassium, mmol/L	
Hemoglobin, g/L	
White cell count, $\times 10^9$/L	
Electrocardiogram	

POSSUM, Physiological and Operative Severity Score for enUmeration of Mortality and Morbidity.
Mortality risk equations (*R* is the risk of mortality): V-POSSUM (Physiology score only): ln (R/1–R) = −6.0386 + (0.1539 × physiologic score). RAA-POSSUM (Physiology score only): ln (R/1–R) = −2.7569 + (0.0968 × physiologic score).

otherwise unsuitable, such as refractory loss of consciousness or cardiac arrest, severe dementia, or poor functional status.

The GAS is calculated using the following formula: risk score = age in years + 17 (for shock) + 7 (for myocardial disease) + 10 (for cerebrovascular disease) + 14 (for renal disease). Shock is defined on clinical grounds by tachycardia, hypotension, pallor, and sweating. Myocardial disease is previously documented myocardial infarction or ongoing angina, or both. Cerebrovascular disease refers to all grades of stroke, including transient ischemic attacks. Renal disease is any or all of a history of chronic or acute renal failure, urea level >20 mmol/L, or a creatinine level >150 μmol/L at presentation.[3]

The Hardman Index is derived from five preoperative variables: age >76 years, serum creatinine level >190 μmol/L, hemoglobin level <9 g/dL, myocardial ischemia on electrocardiograph, and a history of loss of consciousness after hospital arrival.[4] A patient may score between 0 (no Hardman variables present) and 5 (5 Hardman variables present). It has been reported that the presence of ≥3 variables is uniformly fatal.[8,9]

The POSSUM represents a risk-prediction model based on a physiology score derived from 12 preoperative variables, independently predictive of adverse postoperative outcome on multivariate analysis, and an operative score derived from six further intraoperative variables. To allow for preoperative risk scoring, the physiology score may be subjected to risk equations developed for vascular surgery (V-POSSUM) and ruptured AAA (RAAA-POSSUM) that convert the scores into a predicted percentage mortality (Table I).[5,10]

The ERAS derives from three preoperative variables: hemoglobin level <9 g/dL, a best-recorded in-hospital Glasgow Coma Scale of <15, and a recorded in-hospital blood pressure of <90 mm Hg. A patient may score ≤1, 2, or 3, depending on the number of variables present. These bands of risk correspond to a predicted mortality of 30%, 50%, and 80%, respectively.[6]

Table II. Primary reason for refusal of surgery in 27 patients

Reason for refusal	*Patients, No.*
Refractory cardiac arrest/LOC	13
Cardiorespiratory comorbidity	6
Age-related comorbidity	5
Patient wishes	2
Disseminated malignancy	1

LOC, Loss of consciousness.

Statistical analysis was performed using SPSS 13.0.0 software (SPSS Inc, Chicago, Ill). The receiver-operator characteristic (ROC) curve and χ^2 test for trend was used to compare the performance of the GAS, Hardman Index, POSSUM models, and ERAS in predicting postoperative death. The POSSUM-predicted mortality was evaluated by means of the χ^2 test, using the methods described by Hosmer and Lemeshow as appropriate,[11,12] and $P \leq .05$ was considered significant.

RESULTS

During the study period, 111 patients were admitted with ruptured AAA, and 27 (24%) were deemed unfit for aneurysm repair due to prohibitive comorbidity. There were 17 men and 10 women of a median (interquartile range) age of 79 (73-84) years. Reasons for nonoperative management are listed in Table II. Risk scores for the GAS, Hardman Index, V-POSSUM and RAAA-POSSUM mortality scores, and ERAS in the 11 patients who were turned down for surgery on the basis of comorbidity (apart from advanced malignancy) are summarized in Table III.

The remaining 84 patients underwent attempted repair of ruptured AAA and are included in the present analysis. There were 74 men and 10 women of a median (interquartile range) age of 73 (67-78) years. Thirty-seven patients (44%) died after operation, whereas of all patients admitted to hospital with a ruptured AAA during the study period, 63 (57%) died. One patient who did not undergo attempted repair survived her ruptured AAA and was discharged to a nursing home.

Glasgow Aneurysm Score. The mortality rates in terms of tertiles of GAS distribution are summarized in Table IV. The GAS was statistically related to death after attempted repair of ruptured AAA. The median (interquartile range) GAS was significantly greater in patients who survived operative repair than those who did not: 90 (82-106) vs 99 (91-112; $P = .027$). Analysis of the ROC curve showed that the GAS had an area under the curve (AUC) of 0.64 (95% confidence interval [CI], 0.52-0.76) for predicting perioperative death.

Hardman Index. The mortality rates in terms of Hardman Index distribution are summarized in Table V. There was a significant association between the Hardman

Table III. Risk scores in 11 patients who were palliated due to comorbidity

Patient	*Reason for palliation*	*Age*	*GAS*	*HI*	*V-POSSUM mortality, %*	*RAAA-POSSUM mortality, %*	*ERAS*
1	Cardiac dysfunction, suprarenal AAA	73	107	0	41	70	1
2	Cardiac dysfunction, suprarenal AAA	79	96	1	38	67	1
3	Cardiac dysfunction, chronic renal failure	83	121	3	88	91	2
4	Cardiac dysfunction	87	111	4	88	91	3
5	Cardiac dysfunction, chronic renal failure	89	120	3	57	77	2
6	Severe COPD	80	97	1	31	63	1
7	Previous disabling stroke	71	120	2	79	87	2
8	Pre-existing severe brain injury	76	100	1	31	63	2
9	Severe dementia	76	110	2	45	72	2
10	Extreme age	92	116	2	71	83	3
11	Extreme age	92	119	1	15	49	2

AAA, Abdominal aortic aneurysm; *COPD,* chronic obstructive pulmonary disease; *ERAS,* Edinburgh Ruptured Aneurysm Score; *GAS,* Glasgow Aneurysm Score; *HI,* Hardman Index; *POSSUM,* Physiological and Operative Severity Score for enUmeration of Mortality and Morbidity; *V,* vascular; *RAAA,* ruptured abdominal aortic aneurysm.

Table IV. Distribution and mortality rates in 84 patients according to tertiles of Glasgow Aneurysm Score

Glasgow Aneurysm Score	*<89*	*89-105*	*>105*
Patients, No. (%)	28 (33)	28 (33)	28 (33)
Deaths, No (%)	8 (29)	13 (46)	16 (57)

Table V. Distribution and mortality rates in 84 patients according to the Hardman Index

Hardman Index	*0*	*1*	*2*	*≥3*
Patients, No. (%)	21 (25)	34 (40)	18 (21)	11 (13)
Deaths, No. (%)	6 (29)	11 (32)	12 (67)	8 (73)

score and operative death ($P = .010$). Analysis of the ROC curve showed that the Hardman score had an AUC of 0.69 (95% CI, 0.57-0.80) for predicting perioperative death.

Edinburgh Ruptured Aneurysm Score. There was a significant association between ERAS score and operative death ($P < .001$; Table VI). Analysis of the ROC curve showed that the ERAS had the largest AUC of 0.72 (95% CI, 0.61-0.83) for predicting perioperative death.

Possum. The ROC curve analysis showed that the POSSUM models had an AUC of 0.70 (95% CI, 0.59-0.82) for predicting perioperative death. Table VII summarizes the predicted risk of death and observed mortality rate for each of the POSSUM models used. The V-POSSUM (physiology only) model did not demonstrate any lack of fit. However, the RAAA-POSSUM (physiology only) model demonstrated a significant lack of fit ($P = .009$).

DISCUSSION

Although there have been several attempts to devise a prognostic score with which to predict outcome in patients with ruptured AAA, few have undergone robust validation. The use of an imprecise predictive tool to justify clinical decision making is open to question.

Table VI. Distribution and mortality rates in 84 patients according to Edinburgh Ruptured Aneurysm Score

Edinburgh Ruptured Aneurysm Score	*≤1*	*2*	*3*
Patients, No. (%)	46 (55)	27 (32)	11 (13)
Deaths, No. (%)	12 (26)	16 (59)	9 (82)

Previous validation of the GAS has come from prospective data pooled from three Scottish centers, retrospective data from the multicenter Finnvasc database, retrospective data from a tertiary vascular center in Rome, and from our own institution.[13-16] Apart from the Edinburgh data, the other data sets commend the GAS for its predictive power and validity. Of interest is that the more recent data from Rome noted that no patient with a GAS of >100 survived, whereas the Finnish data describe a mortality rate of approximately 80% for patients with a score of >98.[15,16] Similarly, the original Glasgow authors reported that scores of >95 were associated with a mortality rate of 80%.[14]

The present prospective data contradict the findings of these three previous series. Although the GAS was statistically associated with death, the performance of the instrument is much less precise. Patients with scores of <90 are at low risk, but it appears difficult to identify the group of most interest: those patients at extreme risk. Potential reasons for the contrasting performance of the GAS when applied to our data have been described.[13] Most of the preceding data stem from low-volume institutions that operate on <20 patients with ruptured AAA each year. It seems likely that the relationship between hospital and surgeon volume and improved outcome is likely to be important.[17]

Ten series have examined the validity of the Hardman Index; only one has been prospective.[3,8,9,13,16,18-22] Initial reports and consensus was that the Hardman Index accurately predicted death after ruptured AAA. The presence of three or more variables was widely held to be fatal[8,9]; however, more recent data have shown that the instrument

Table VII. Predicted and observed mortality according to V-POSSUM (physiology only) and RAAA-POSSUM (physiology only) models

	Predicted risk			*Mortality*			*Overall result for each model*	
	Range, %	*Mean, %*	*Range, No.*	*Predicted*	*Observed*	χ^2	χ^2	P
V-POSSUM	0-31	16	44	7	13	6.61		
	31-50	42	17	7	7	0.01		
	50-70	59	12	7	9	1.21		
	70-100	80	11	9	8	0.32		
	0-100	36	84	30	37		8.16	.086 (4df)
RAAA-POSSUM								
	0-55	41	31	13	9	1.91		
	55-70	63	23	15	8	8.13		
	70-80	75	15	11	9	1.73		
	80-100	86	15	13	11	1.86		
	0-100	61	84	51	37		13.63	.009 (4df)

POSSUM, Physiological and Operative Severity Score for enUmeration of Mortality and Morbidity; *V,* vascular; *RAAA,* ruptured abdominal aortic aneurysm.

does not perform as well as initially reported.[13,19-22] The present prospective data confirm that the Hardman Index does not display as convincing validity as initially reported. Although increasing score is associated with death, its predictive ability is only moderate, and the Hardman Index does not clearly identify patients who are at extreme risk in whom attempted operation is futile. The merits of the present data are not only its prospective nature but also the fact that only one patient had an incomplete set of scoring data. In the existing literature, data have been unavailable for up to 42% of patients.[22] Indeed, in the only other reported prospective study, data were missing on almost a third of patients.[9]

The POSSUM score is a tool that was designed to support comparative audit. It is important to recognize that it has never been recommended for outcome prediction. No prospective validation of the POSSUM risk equations recommended for vascular surgery when applied to patients with ruptured AAA has been reported. Of the existing retrospective literature, both the RAAA-POSSUM and V-POSSUM equations were shown accurately to predict risk when applied to preoperative data on 191 patients from Gloucester.[18] From the present preoperative data, both equations perform less well, although only the RAAA-POSSUM model demonstrated a significant lack of fit. The RAAA-POSSUM model over-predicted risk, whereas the V-POSSUM model tended to under-predict at the lower bands of risk. This lack of fit raises concerns about its use as a risk-stratification tool for comparative audit of death from ruptured AAA. Reasons for the discrepancy are unclear, but further validation of this model is needed.

The ERAS was modelled on retrospective data from patients presenting to our institution with ruptured AAA during a 2-year period. It has had no internal or external validation and cannot be recommended for clinical use at present. When applied to the present data, the score was significantly associated with perioperative death. The appeal of this scoring system is its simplicity and the ease with which the three components of the score can be obtained and applied, and even the hemoglobin concentration can be rapidly assessed using point-of-care testing. Furthermore, as observed on the initial data set, three tiers of risk are discernible. The limitations of this scoring system are acknowledged. It has been specifically modelled on a unique data set and may not be applicable or show validity on external data.

CONCLUSION

To our knowledge, these are the first prospective data to evaluate comprehensively the main scoring instruments recommended for use in ruptured AAA repair. The GAS and Hardman Index do not perform as predictive instruments as well as previously reported. Furthermore, the V-POSSUM and RAAA-POSSUM also do not demonstrate compelling validity when applied to these data. The ERAS is an easily applied scoring system that allows patients to be quickly and accurately allocated to a low, medium, and high risk of perioperative death. It does not enable the prediction of surgical futility, however; further external assessment is required to confirm its validity.

AUTHOR CONTRIBUTIONS

Conception and design: AT, JM, RC
Analysis and interpretation: AT, JM, RC
Data collection: AT
Writing the article: AT, JM, RC
Critical revision of the article: AT, AL, JM, RC
Final approval of the article: AT, AL, JM, RC
Statistical analysis: AT
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